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The Spectrum of the Corona, 1914 August 21.

By the Rev. A. L. Cortie, S.J.

In the Preliminary Report of the Total Solar Eclipse of 1914 August 21, observed at Hernösand, Sweden,* a full description was given of the spectrograph, of the Littrow form, which was employed to photograph the spectrum of the corona, and of the arrangements made to photograph the arc-spectrum of iron on the same plate. The adjustment of the instrument was as follows:—

Objective.—Achromatic lens, 6 inches aperture, 98 inches focal length.

Reflector.—Flat silver-on-glass mirror, $6\frac{1}{2}$ inches diameter.

Prism.—Dense flint, 7 inches edge, refracting angle 40°.

Deviation of prism.—At H_β, 28·5°.

Slit.—$\frac{7}{8}$ inch by 0·0017 inch.

Purity of spectrum.—6400 at λ 5270.

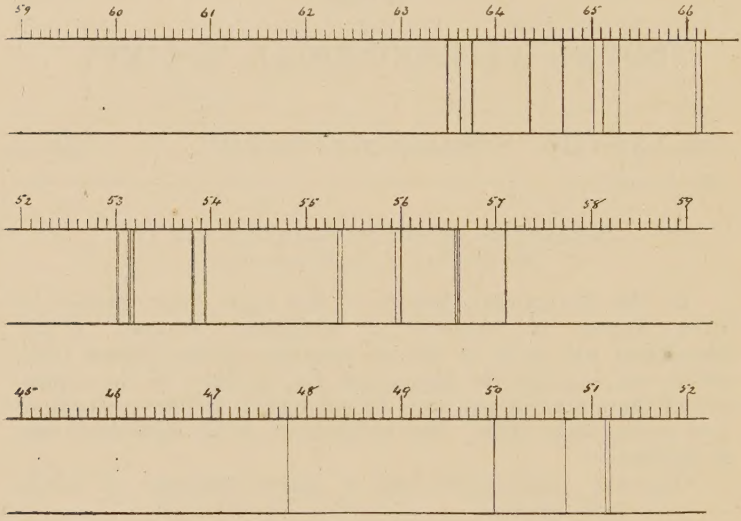
The slit was placed almost tangential to the sun's limb at the point of second contact. The image of the eclipsed sun on the slit, $\frac{1}{16}^{3}$ inches in diameter, was formed by an Alvan Clark achromatic lens of 5 inches aperture and 7 feet focal length. Judging from the photograph of the coronal lines, it would seem better on future occasions to employ an instrument with a fewer number of optical surfaces to reflect and absorb the faint light of the corona. Also it would probably have been better to have employed a wider slit, and a smaller and brighter image on the slit.

The resulting spectrum of the corona is excessively faint. The lines, though for the most part sharp, are very difficult to see and to measure. In the plate which accompanies the Astronomer

* *Monthly Notices, R.A.S.*, 75, 105–117.

Royal's memoir * on the chromospheric and coronal spectra during eclipses, the coronal line at λ 5117, which was "slightly accentuated to make it clearly visible on the plate." is given an intensity 2 in the table. Taking this as a guide, the most pronounced lines on the plate of 1914 may be given an intensity 1, and those quite on the limit of clear vision an intensity 0. They have been so entered in the following table. The lines in the comparison spectrum of the iron arc were identified by means of the map of MM. H. Buisson et Ch. Fabry,† and their wave-lengths were taken from the table of Dr. Keivin Burns.‡

The wave-lengths of the coronal lines between λ 5709 and



Spectrum of the Solar Corona, 1914 August 21.

λ 4780 were determined by interpolation between neighbouring iron lines. For the red end of the spectrum, where the iron lines are less numerous, besides interpolation, a curve was constructed upon nine fiducial iron lines between the lines at λ 6338·9 and λ 6678·0 In addition, a graphical representation of the Hartmann-Cornu formula, according to the method of Dr. Henroteau,§ was employed. The resulting wave-lengths in this portion of the spectrum are the mean values of the three separate determinations. For the important line in the red at wave-length about 6370, five separate determinations were made from the curve, the graph, and by interpolation between iron lines. The

* *Memoirs, R.A.S.*, Appendix to vol. 57, pp. [49], [50].

† *Annales de la Faculté des Sciences de Marseille*, tome xvii., fascicule iii., 1908.

‡ *Lick Observatory Bulletin*, No. 247.

§ *Monthly Notices*, 77, 77.

resulting value is 6373·3. The value of this radiation given by Carrasco was 6373·87, and by Deslandres 6374·5. Possibly the measures refer to different parts of the line, which was slightly curved, or were made at different places in the corona. The separate determinations of the lines in the red are sufficiently close to make it unlikely their probable error is more than one Angstrom unit.

In such a faint spectrum careful judgment had to be exercised to discriminate real lines from possible photographic markings. But confidence in the reality of the lines given in the table was afforded by the fact that their positions, though determined quite independently of any previous knowledge, agree almost exactly with several lines given in Dyson's table, and with those given for this same eclipse by Furuhjelm.* The lines given by the latter observer at λ 5393·5 and λ 5381·1 were looked for and found, but that given at λ 5433·6 could not be identified. A plate has been drawn containing the lines which appear to be present without any doubt. There is some evidence of a banded spectrum in the red, especially if the doubtful lines be included, but more evidence of double and triple lines suggesting a series spectrum.

Wave-length.	Intensity.	Remarks.
6615·7	1	Mean of three separate determinations.
6608·8	0	,, ,, ,,
6567·4	1	Probably C line, hydrogen, displaced.
6528·9	0	Mean of three separate determinations.
6511·6	0	,, ,, ,,
6501·9	0	,, ,, ,,
6470·4	1	,, ,, ,,
6435·5	1	,, ,, ,,
6379·0	0	Doubtful.
6376·9	0	,,
6373·3	1	Mean of five separate determinations. Carrasco 73·9 ; Deslandres 74·5.
6371·6	0	Doubtful.
6363·4	0	Ricco 6363 to 6367.
6348·8	1	
5709·8	1	
5660·8	0	
5659·3	0	Doubtful.
5657·4	0	Furuhjelm 5657·7. Independent determination.
5596·9	1	Furuhjelm 5597·7. ,, ,,
5594·5	0	
5537·5	0	

* *Note sur le spectre de la couronne solaire intérieur, etc.*, Helsingfors, 1915.

Wave-length.	Intensity.	Remarks.
5534·1	0	Furuhjelm 5534·8; Dyson 5535·8. Independent determinations.
5395·2	0	
5394·3	0	Furuhjelm 5393·5.
5381·4	0	Furuhjelm 5381·1.
5379·6	1	
5317·9	1	
5315·4	0	
5313·1	0	
5302·8	0	Dyson 5303·1; Furuhjelm 5303·4 and 5302·7. Independent determinations.
5300·6	0	
5118·1	0	Dyson 5117·7. Independent determinations.
5114·3	0	
5071·8	0	Dyson 5073. ,, ,,
4997·1	1	
4780·0	0	Dyson 4779. ,, ,,

Stonyhurst College Observatory:
1918 *August* 15.

On the Distribution of the Stars. By H. C. Plummer, M.A.

1. In his memoir * on "The Harvard Map of the Sky and the Milky Way," Mr. H. Nort has provided in a convenient form excellent material for a study of the distribution of the stars. In spite of the critical remarks which he makes himself, this material is probably the most complete and uniform within its limits at present accessible. The *Bonn Durchmusterung* is quite unsatisfactory for the purpose, and counts to a very low order of magnitude must always be carried out by the method of samples. It is thus that a tendency has arisen to treat any variation of star density according to galactic longitude as accidental and unimportant, a tendency which must always seem surprising to those who have had experience of the results of photographing systematically a definite and considerable region of the sky. The idea can hardly survive a perusal of Mr. Nort's work.

2. For the preliminary consideration of this material spherical harmonic analysis is obviously suggested. It is a method which has not been widely used for the purpose, but the examples † of Professor Turner and Mr. F. G. Brown may be quoted. By this

* *Recherches Astronomiques de l'Observatoire d'Utrecht*, vii.
† *M.N.*, **72**, 203, 718.

means a complicated set of facts is resolved, without assumptions, into a number of definite, independent components, expressed appropriately in reference to a sphere. It soon becomes evident that the facts of stellar distribution are exceedingly complex, apart altogether from any question of explanation. The irregularities which occur are not to be dismissed as merely due to local aggregates or seasonal effects on the observations, leaving one simple phenomenon to be recognised as galactic condensation and to be traced out, on the assumption of symmetry, in relation to different orders of magnitude. Local irregularities, of course, exist, and what is wanted in the first place is a specification as far as possible independent of them. For this object an analysis in spherical harmonics is the most appropriate method.

3. In what follows ϕ will be used for galactic longitude and θ for galactic N.P.D. Mr. Nort's table xxxiii. (p. 113) gives the mean star density for ranges of 10° in ϕ in zones differing by 20° in θ. The first step is to analyse these zones so as to express the density in the form

$$d = a_0 + \Sigma(a_r \cos r\phi + b_r \sin r\phi).$$

For this purpose the mean density is taken at 24 equidistant points round each of the middle zones, and at 12 points round each of the six outer zones. Thus the whole is based on the mean density at 144 points, each representing a considerable area. The analysis might be made in a more elaborate way by using the more complete tables of density, but this course should bring out the more prominent facts. The results of this preliminary analysis are given in Table I. It is convenient to leave in the multiplier 6 and to omit decimals. Thus the numbers refer directly to the numbers of stars in 6 square degrees.

TABLE I.

θ.	$6a_0$.	$6a_1$.	$6b_1$.	$6a_2$.	$6b_2$.	$6a_3$.	$6b_3$.	$6a_4$.	$6b_4$.	$6a_5$.	$6b_5$.
°											
10	49	1	− 4	− 4	5	− 3	− 3	0	1	− 1	0
30	67	− 5	− 4	12	− 4	− 10	4	0	− 8	− 3	0
50	89	10	− 1	14	− 7	− 7	9	16	− 7	0	13
70	161	27	− 24	6	− 4	− 16	38	14	5	20	26
90	274	50	− 87	− 80	22	− 50	76	42	− 26	14	− 21
110	185	37	− 36	− 54	42	− 38	28	21	− 3	0	− 20
130	131	30	− 15	− 4	24	− 1	2	0	− 10	10	− 1
150	117	8	− 29	− 7	18	− 8	8	3	14	− 6	13
170	89	8	− 8	− 7	− 2	− 9	− 9	1	− 2	4	− 4

Table I. seems deserving of some attention as it stands. There are, of course, some irregularities, chiefly associated with the asymmetry between the upper and lower hemispheres. But on the whole the evidence of regular structure is much more

remarkable. The periodic variations of the density in the galaxy are marked, and the same rhythmical structure can generally be traced as far as the two polar regions. This appearance of consistency seems enough to confirm the reality of the variations in the galaxy itself, and at the same time to show that the same structural features extend in the main to all parts of the sky. Emphatically there can be no question here of merely local cloud masses, disturbing as they must be to any form of analysis.

4. A spherical analysis can now be based on Table I. The constant term of zero order is 153, giving on division by 6 an average of 25·5 stars per square degree to the eleventh visual magnitude.

The terms of the first order are represented by

$$34 \sin\theta \cos\phi - 41 \sin\theta \sin\phi - 29 \cos\theta = 60{\cdot}6 \cos\theta_1,$$

where θ_1 is the angular distance measured from the point

$$\phi = 309^\circ{\cdot}7, \quad \theta = 118^\circ{\cdot}6; \qquad \alpha = 293^\circ{\cdot}0, \quad \delta = -55^\circ{\cdot}0.$$

These terms present an unforeseen and apparently important phenomenon. They indicate a steady gradient over the whole sky, extending from the point of maximum density just determined to the opposite pole. This feature can scarcely be treated as insignificant, for it means a maximum variation of ± 10 stars per square degree from the diametral plane, and this is no small amount, since the general average is of the order 25. It seems altogether independent of what is commonly understood by the galaxy, and is associated with the recognised excess in the stellar density of the southern hemisphere. But the actual situation of the axis of this first-order gradient was unexpected.

For comparison it may be appropriate to recall that Eddington and Hartley * found for the situation of the greatest axis of the velocity ellipsoid for the distant K – K2 stars

$$\alpha = 116^\circ{\cdot}1, \qquad \delta = +43^\circ{\cdot}0.$$

This alone may carry little suggestion, but more recently R. Furuhjelm † has found for the position of the vertex

$$\alpha = 134^\circ, \qquad \delta = +43^\circ.$$

This is based on the stars, relatively faint, in a small part of the Helsingfors Astrographic Catalogue. Of itself the determination would have small weight, but it is additional evidence that the vertex is no definite point for all classes of stars. The first-order gradient in the distribution may therefore have an influence on the motions of the stars.

5. The second-order terms are found to give

$$-30(1 + 3\cos 2\theta) + (-8\cos\phi + 8\sin\phi)\sin 2\theta + (-19\cos 2\phi + 10\sin 2\phi)(1 - \cos 2\theta).$$

* *M.N.*, 75, 526. † *Acta Soc. Sci. Fennicæ*, 48, 1.

On writing

$$x = \cos\phi \sin\theta, \quad y = \sin\phi \sin\theta, \quad z = \cos\theta$$

this expression becomes

$$\begin{aligned} &22\,x^2 + 98\,y^2 - 120\,z^2 + 16\,yz - 16\,zx + 40\,xy \\ &\quad = 18\,\xi^2 + 103\,\eta^2 - 121\,\zeta^2 \end{aligned}$$

where

$$\begin{aligned} \xi &= \cdot 969\,x - \cdot 235\,y - \cdot 071\,z. \\ \eta &= \cdot 237\,x + \cdot 971\,y + \cdot 026\,z. \\ \zeta &= \cdot 062\,x - \cdot 042\,y + \cdot 997\,z. \end{aligned}$$

The directions of the (ξ, η, ζ) axes are

$$\begin{aligned} \xi &: \ \phi = 346^\circ\cdot 4, \quad \theta = 94^\circ\cdot 1 ; \qquad \alpha = 278^\circ\cdot 4, \quad \delta = -13^\circ\cdot 9. \\ \eta &: \ \phi = \ 76^\circ\cdot 3, \quad \theta = 88^\circ\cdot 5 ; \qquad \alpha = 341^\circ\cdot 4, \quad \delta = +61^\circ\cdot 3. \\ \zeta &: \ \phi = 325^\circ\cdot 7, \quad \theta = \ 4^\circ\cdot 3 ; \qquad \alpha = 195^\circ\cdot 0, \quad \delta = +24^\circ\cdot 6. \end{aligned}$$

When the constant term is added in the form $153\,(\xi^2 + \eta^2 + \zeta^2)$ the result is

$$171\,\xi^2 + 256\,\eta^2 + 32\,\zeta^2,$$

or, for the number of stars per square degree (on division by 6),

$$28\cdot 5\,\xi^2 + 42\cdot 7\,\eta^2 + 5\cdot 3\,\zeta^2.$$

The axis of ζ is naturally near the axis of the Milky Way, though not coincident with it. The axis of ξ seems to point unmistakably to the vertex. The axis of η is still nearer to the galactic plane, and this is the axis which indicates the direction of greatest density. In the galactic plane the least density is in the direction of the axis of ξ, and since this is the direction of greatest mobility it appears that the stellar system is not in a steady state, but that a process of diffusion is tending to bring about a condition of greater uniformity in the galactic distribution. The point of importance is the association of the second-order distribution with the vertex of preferential motion, and this appears definite.

6. The harmonics of the first two orders are doubtless the most important, but they are clearly insufficient to represent a very complex distribution. Terms of the third order may be expressed in the form

$$\begin{aligned} &+ 7(\tfrac{3}{8}\cos\theta + \tfrac{5}{8}\cos 3\theta) \\ &+ (-16\cos\phi + 26\sin\phi)(\tfrac{1}{6}\sin\theta + \tfrac{5}{6}\sin 3\theta) \\ &+ (\ 21\cos 2\phi - 21\sin 2\phi)(\tfrac{2}{5}\cos\theta - \tfrac{2}{5}\cos 3\theta) \\ &+ (-37\cos 3\phi + 50\sin 3\phi)(\tfrac{3}{4}\sin\theta - \tfrac{1}{4}\sin 3\theta). \end{aligned}$$

The harmonic functions are here expressed with such coefficients that their greatest numerical values are approximately ± 1. The

common factor 6 has been retained, and when this is removed the results can be written in the form

$$\begin{aligned} &+ 1{\cdot}2(\tfrac{3}{8}\cos\theta + \tfrac{5}{8}\cos 3\theta) \\ &+ 5{\cdot}1\sin(\phi + 324^\circ)(\tfrac{1}{6}\sin\theta + \tfrac{5}{6}\sin 3\theta) \\ &+ 5{\cdot}0\sin(2\phi + 135^\circ)(\tfrac{2}{3}\cos\theta - \tfrac{2}{3}\cos 3\theta) \\ &+ 10{\cdot}4\sin(3\phi + 323^\circ)(\tfrac{3}{4}\sin\theta - \tfrac{1}{4}\sin 3\theta). \end{aligned}$$

The sectorial harmonic of the last line is the most important; its maxima occur at $\phi = 42^\circ$, 162°, 282°. The maximum at $\phi = 162^\circ$ again suggests a close association of this harmonic with the vertex. Moreover, two recent investigations, those of G. Strömberg* and B. Boss,† have both indicated a shape for the velocity figure which the latter compares with a clover leaf.

7. The preponderant density in the Milky Way itself is naturally difficult to represent. We may add the two zonal harmonics of even order

$$+ 13{\cdot}2\,P_4 - 8{\cdot}7\,P_6$$

for the number of stars per square degree, where

$$\begin{aligned} 64\,P_4 &= 9 + 20\cos 2\theta + 35\cos 4\theta \\ 512\,P_6 &= 50 + 105\cos 2\theta + 126\cos 4\theta + 231\cos 6\theta. \end{aligned}$$

The coefficient of P_5 is relatively small.

8. Two particular cases of the general formulæ are of special interest. These refer to the mean galactic meridian and the galactic plane itself. The first contains the zonal harmonics only, and can be expressed in the form

$$21{\cdot}5 - 4{\cdot}4\cos\theta - 12{\cdot}7\cos 2\theta + 0{\cdot}7\cos 3\theta + 5{\cdot}1\cos 4\theta - 3{\cdot}9\cos 6\theta$$

stars per square degree. The resulting densities are given under C in the right-hand section of Table II., and compared with the observed average densities (O) for the zones 20° apart. The agreement is very fair, as it should be, since the zonal harmonics are based on these zone averages.

For the galactic plane the formula is obtained by writing $\theta = 90^\circ$. It is

$$43{\cdot}2 + 12{\cdot}3\sin(\phi + 142^\circ) + 7{\cdot}1\sin(2\phi + 298^\circ) + 10{\cdot}4\sin(3\phi + 323^\circ)$$

stars per square degree. The calculated densities (C) are given in the left-hand section of Table II., and compared with the observed densities (O).

Here the agreement is not so good, for more than one reason. The numbers observed are subject to purely local irregularities. On the other hand, the formula is derived from the whole sphere, and not simply from the galactic regions. Otherwise the coefficients given in the central line of Table I. would have been

* *Ap. J.*, 47, 7. † *A.J.*, No. 736.

used. The discordances may thus be taken to indicate exceptional regions apart from general structure. The most prominent example is the region of the Southern Cross, between galactic longitudes 250° and 290°, which appears to represent a veritable congested district in the Milky Way.

TABLE II.

Galactic Plane.								Mean Galactic Meridian.			
ϕ.	C.	O.	O−C.	ϕ.	C.	O.	O−C.	θ.	C.	O.	O−C.
°				°				°			
5	40·3	47·5	+ 7·2	185	34·9	46·4	+11·5	0	6·3		
15	45·5	39·5	− 6·0	195	33·3	28·5	− 4·8	10	7·8	8·1	+0·3
25	50·8	34·6	−16·2	205	32·6	27·0	− 5·6	20	11·0		
35	54·3	53·2	− 1·1	215	33·9	25·5	− 8·4	30	12·6	10·8	−1·8
45	55·2	52·1	− 3·1	225	37·8	32·9	− 4·9	40	12·7		
55	52·9	55·6	+ 2·7	235	43·9	41·7	− 2·2	50	13·5	15·0	+1·5
65	48·1	62·2	+14·1	245	51·5	55·1	+ 3·6	60	18·5		
75	41·4	56·1	+14·7	255	59·2	83·5	+24·3	70	28·0	26·5	−1·5
85	34·6	36·7	+ 2·1	265	65·4	92·3	+26·9	80	38·1		
95	28·9	31·0	+ 2·1	275	68·7	93·7	+25·0	90	43·2	45·6	+2·4
105	25·4	19·4	− 6·0	285	68·6	94·6	+26·0	100	40·5		
115	24·5	18·1	− 6·4	295	64·9	75·1	+10·2	110	32·2	30·5	−1·7
125	26·1	19·4	− 6·7	305	58·5	41·2	−17·3	120	24·3		
135	29·1	29·4	+ 0·3	315	50·7	48·0	− 2·7	130	20·3	21·6	+1·3
145	32·7	28·8	− 3·9	325	43·3	45·9	+ 2·6	140	20·3		
155	35·3	37·6	+ 2·3	335	37·9	38·5	+ 0·6	150	20·2	19·1	−1·1
165	36·6	35·8	− 0·8	345	35·6	31·5	− 4·1	160	18·4		
175	36·3	37·3	+ 1·0	355	36·5	45·8	+ 9·3	170	15·2	15·4	+0·2
								180	13·7		

9. Let the galactic star density be represented by $D = D(\phi)$, a function of which the numerical values are given in Table II. This may also be represented by a polar curve (fig. 1) in which the radius vector is proportional to the density in the corresponding direction. There is also a radial velocity surface, of which the galactic section may be represented by $V = V(\phi)$ or by a similar polar curve. This has been done in figs. 3–5 of Strömberg's quoted paper. Between Strömberg's figs. 3 and 4 and the present fig. 1 the resemblance in shape is most striking, but it is necessary to make a change in the orientation by rotating one relatively to the other through 90°. In other words, the relation between density and radial velocity is expressed by

$$D(\phi + 90°) \div V(\phi) = \text{const.}$$

Perhaps the nature of this relation may be better judged from Table III., where V_1, V_2 are the calculated radial velocities, for

very bright and bright stars respectively, taken from Strömberg's table ix., and D is the calculated density taken from Table II. above. It will be seen that the maxima among these figures occur

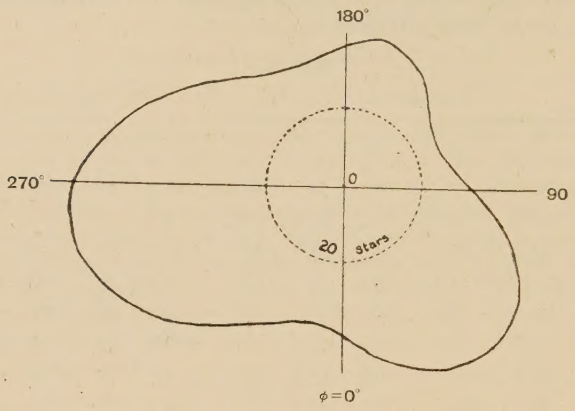


FIG. 1.

at the same places and generally in the corresponding order of magnitude. It is difficult to understand the meaning of these facts, but equally difficult to resist the idea that they have some significance. The coefficient of correlation between $D(\phi+90^\circ)$

TABLE III.

ϕ.	$V_1(\phi)$.	$V_2(\phi)$.	$D(\phi+90^\circ)$.	
15°	12·0	16·0	25·4	
45	12·2	15·5	29·1	
75	13·4	17·6	36·6	Max.
105	11·4	16·8	33·3	
135	11·1	16·5	37·8	
165	16·2	20·4	59·2	
195	19·0	22·1	68·6	Max.
225	13·9	16·3	50·7	
255	8·8	11·5	35·6	
285	11·8	15·9	45·5	
315	17·0	22·6	55·2	Max.
345	15·8	21·3	41·4	

and $V_1(\phi)$ is found to be $+0\cdot80$, and that between $D(\phi+90^\circ)$ and $V_2(\phi)$ is $+0\cdot69$. On the other hand, there appears to be no such relation between the density curve and Strömberg's third velocity curve, which refers to dwarf stars much closer to the Sun. A relation of this kind, when it presents itself, may be

evidence of dynamical structure in the system without indicating any direct causal connection between the star density in one region and the state of motion in another.

10. The results obtained from the Harvard Sky appear worthy of considerable confidence, but they refer to only one definite limiting magnitude. It is now desirable to extend them as far as possible to all magnitudes. For this purpose we may take Mr. Van Rhijn's recent memoir,* with the final results derived in his table iv. They refer to average numbers in galactic zones, and no distinction is drawn between the opposite sides of the galactic plane. Hence it is only possible to deduce the zonal harmonics of even order, but this can be done very readily for each half magnitude from 7 to 16. If N is the average number of stars per square degree brighter than magnitude m at galactic P.D. θ, we may write

$$N = c_0 - c_2 P_2 + c_4 P_4 - c_6 P_6.$$

The values of the logarithms of c_0, c_2, c_4, c_6 are given in Table IV. If c_0 is taken as the standard and log c_0 is subtracted from the three following columns it will be seen that c_2/c_0 increases steadily from mag. 8 onwards, and c_4/c_0 from mag. 10, while c_6/c_0, though naturally more irregular, increases from the same point.

TABLE IV.

m.	log c_0.	log c_2.	log c_4.	log c_6.	c_0'.	c_2'.	c_4'.	c_6'.	C_0.
7·0	9·348	9·231	9·096	9·112	3·53	2·70	1·98	2·05	3·91
7·5	·587	·458	·278	·264	3·86	2·87	1·90	1·84	4·22
8·0	·822	·694	·499	·498	4·19	3·12	1·99	1·99	4·57
8·5	0·060	·941	·725	·744	4·57	3·48	2·11	2·21	4·95
9·0	293	0·182	·955	·928	4·93	3·82	2·26	2·13	5·32
9·5	·528	·419	0·174	0·179	5·35	4·16	2·37	2·39	5·60
10·0	·749	·642	·363	·368	5·61	4·38	2·31	2·33	5·66
10·5	·967	·886	·604	·591	5·85	4·85	2·54	2·46	5·92
11·0	1·189	1·118	·873	·811	6·15	5·22	2·97	2·58	5·96
11·5	·389	·346	1·105	1·018	6·15	5·57	3·20	2·62	5·65
12·0	·588	·572	·336	·221	6·14	5·92	3·44	2·64	5·46
12·5	·775	·782	·542	·382	5·96	6·05	3·48	2·41	4·95
13·0	·949	·984	·785	·622	5·61	6·08	3·85	2·64	4·34
13·5	2·111	2·164	·972	·799	5·14	5·81	3·73	2·51	3·87
14·0	·277	·330	2·162	·988	4·75	5·37	3·65	2·44	3·58
14·5	·437	·515	·358	2·215	4·34	5·19	3·61	2·60	3·17
15·0	·594	·688	·519	·385	3·93	4·88	3·30	2·43	2·80
15·5	·748	·853	·681	·524	3·53	4·50	3·03	2·11	2·45
16·0	·895	3·004	·838	·668	3·13	4·02	2·74	1·85	2·08

* *Groningen Publications*, No. 27.

This expresses in a little more detail the feature known as the galactic condensation of faint stars, which only becomes apparent after the tenth magnitude.

11. The limiting magnitude to which Nort's reduction refers is the photographic magnitude corresponding to the visual magnitude 11·0 on the Harvard scale. This indirect expression can be replaced by its direct photographic equivalent. We have found that

$$N = 25{\cdot}5\ P_0 - 20{\cdot}0\ P_2 + 13{\cdot}2\ P_4 - 8{\cdot}7\ P_6$$

or

$$\log c_0 = 1{\cdot}406, \quad \log c_2 = 1{\cdot}301, \quad \log c_4 = 1{\cdot}121, \quad \log c_6 = 0{\cdot}940.$$

Now from Table IV., with photographic magnitude 11·5,

$$\log c_0 = 1{\cdot}389, \quad \log c_2 = 1{\cdot}346, \quad \log c_4 = 1{\cdot}105, \quad \log c_6 = 1{\cdot}018$$

whence the differences

$$+{\cdot}017, \quad -{\cdot}045, \quad +{\cdot}016, \quad -{\cdot}078,$$

of which the equivalents in magnitude are

$$+{\cdot}04, \quad -{\cdot}10, \quad +{\cdot}03, \quad -{\cdot}19.$$

The fourth number has little weight, and the simple mean of the first three gives −0·01, indicating that the limiting photographic magnitude is 11·49. For this point Table IV. gives

$$N = 24{\cdot}3\ P_0 - 21{\cdot}9\ P_2 + 12{\cdot}6\ P_4 - 10{\cdot}3\ P_6.$$

The agreement with the formula based on the Harvard Sky is not perfect, but in view of the independence of the material the consistency seems quite as good as was to be expected, and is eminently satisfactory.

12. The equivalence of a photographic and a visual magnitude scale must be taken in a statistical sense, depending on the mixture of colour indices and varying not only through the scale but with the part of the sky concerned. For the sky as a whole the relation should be definite. If m is the photographic magnitude and μ the corresponding visual magnitude, a relation between m and μ has been deduced by Van Rhijn in a tabular form from $m = 5$ to $m = 16$. It may be convenient to express the same equivalence in the form

$$+0{\cdot}0044\ m\mu - 1{\cdot}006\ m + 0{\cdot}956\ \mu + 0{\cdot}49 = 0,$$

which reproduces the tabular figures in the stated range with no error amounting to 0·02, and from which either magnitude can be derived from the other with equal facility. Now according to this formula the photographic magnitude $m = 11{\cdot}49$ is the equivalent of the visual magnitude $\mu = 11{\cdot}00$. This shows that the standard aimed at in the reduction of the counts has been very exactly reached. The evidence of consistency seems fairly complete. If

the Harvard scales are not perfect, at least they have introduced this important quality into the results.

13. In tabulations of the numbers N of stars brighter than successive magnitudes (or half magnitudes), since the numbers increase at a very rapid rate, it has been usual to record log N instead of N. This is no doubt a very convenient plan for some purposes. But another plan seems to offer some advantages. This consists in introducing the factor $10^{-0{\cdot}4m}$ and in tabulating the number M, where

$$M = N \,.\, 10^{4-0{\cdot}4m}.$$

Thus if M be tabulated instead of log N over the extent of Van Rhijn's table iv., from mag. 7 to mag. 16, and from the galaxy to the pole, the numbers run from the maximum 11 down to a little below 1. The natural numbers are therefore quite manageable. They can, of course, convey no information not contained in the other form of tabulation, but they present it in some respects more suggestively. If the stars were all of one standard luminosity and distributed through space with a density inversely proportional to the distance, M would tend to a constant value. As it is, the variations of M indicate the effect of varying mixtures of types and density in space, and so contrast the actual with this infinite system. From this point of view there is certainly no galactic condensation of faint stars. On the contrary, from mag. 12 onwards there is a progressive deficiency of faint stars in the galaxy. But there is a still greater and more rapidly increasing deficiency in the polar regions. This is not a material point of difference, but the term polar deficiency would seem more in harmony with the facts than galactic condensation.

14. The numbers c_0', c_2', c_4', c_6' given in Table IV. have been similarly derived from log c_0, . . ., so that

$$c_j' = c_j \,.\, 10^{4-0{\cdot}4m}.$$

Perhaps the most notable feature of these columns is the immediate evidence of resemblance between the actual universe and the chosen model, for the smallest number in any one column, with only two exceptions at the beginning of the second, is never less than half the largest. The tabulation is also quite convenient, for the ratio of the smallest number to the largest of all is 0·3. Compared with the model the average for the whole sky increases up to mag. 11 and then steadily declines. The turning-point for the second and fourth harmonics is mag. 13. The sixth harmonic is a little uncertain, but its decline seems to set in decisively at mag. 15. It appears that the thinning out of the stars begins at no widely different points in the galaxy and in the polar regions, for the original table of M shows that while $11^{m}{\cdot}0$ is the turning-point in the former, $10^{m}{\cdot}0$ is the turning-point in the latter. But this only regards the factor of star density and ignores the parallel effect of dispersion in luminosity.

15. The tabulation in M is most convenient for questions concerning the integrated light of the stars. Since

$$N = M \cdot 10^{0{\cdot}4m-4}$$
$$\frac{dN}{dm} = \left(\frac{dM}{dm} + 0{\cdot}4\ M \log_e 10\right) 10^{0{\cdot}4m-4}$$

it follows that, if L is the light of all the stars brighter than mag. m,

$$\frac{dL}{dm} = J\left(\frac{dM}{dm} + 0{\cdot}921\ M\right) 10^{-4}$$

where J is the light of one star of mag. 0. For the differential coefficient of M the simple difference between the following and preceding half magnitude can be substituted. Thus we have the ordinates of a curve of which the area represents the integrated starlight per square degree coming from the stars in any given range of magnitude. A formula of interpolation really gives no help, and by proceeding graphically the true nature of the problem is much more clearly seen. Mr. Van Rhijn in his table v. has reduced Professor Kapteyn's earlier results to a corrected visual scale. The numbers in the zone $\pm 10°$ give a curve with an area of 125 between magnitudes 5·5 and 15·5. This is ·0125 as a fraction of a star of magnitude 0, or ·0314 as a fraction of a first-magnitude star, naturally in fair agreement with ·032 found by Van Rhijn. It may also be expressed as the light of one star of mag. 4·8 per square degree. The few brighter stars are left out of account. But the question of the very faint stars remains. An interpolation formula gives a definite result for the remainder, but has it any validity? Van Rhijn increases the ·032 to ·038 (a star of mag. 4·55). Carrying on the curve graphically without any offence to the eye, we find ·042 (a star of mag. 4·45). But the area contained between the infinite branch of a curve and an asymptote can be anything whatever, and nothing should disguise the fact that we are simply guessing. The point made here is that our knowledge in this matter cannot in the nature of things be derived from any counts. From a small piece of a curve it is absolutely impossible to gain any certain idea of the nature of the function at infinity. That the remainder is not large we know by immediate experience. That it really is quite small we see, not by any manipulation of the actual counts, but by special observations of another kind. Thus Mr. Van Rhijn gives the total fraction ·057 (a star of mag. 4·1), and the difference ·025 must be reduced considerably on account of terrestrial and zodiacal light in order to find the residue from the stars below any limit to which the counts are carried. This at least seems the proper order, and the great value of the independent measure of integrated starlight is the upper limit set to the results obtained from counts however far they are extended, for this gives a check on the magnitude scale, a criterion which Kapteyn's earlier scale was very far from satisfying. If this view of the extrapolation to infinity in the case

of total starlight is sound, it applies with much more obvious force to attempts which have been made to estimate the total number of the stars. This has not been done, of course, in a serious spirit, but it seems doubtful if it would have been done at all if the problem had been regarded in the form: being given the (m, M) curve as far as $m = 16$ or 17, to determine Lim. $10^{0.4m}$ M as m tends to infinity. The appearance of the curve is not encouraging.

16. The last column of Table IV. above gives the value of

$$C_0 = \frac{dc_0'}{dm} + 0.921\, c_0'.$$

It is convenient to introduce the factors $360^2/\pi$ for the area of the whole sky and $10^{0.4}$ to make the unit a star of mag. 1 on the photographic scale. Hence if L is the amount of starlight from the whole sky to the limit m,

$$\frac{dL}{dm} = 10.36\, C_0.$$

It follows that the contribution of all the stars between magnitudes 7 and 16 is, at least roughly, equivalent to 422 first-magnitude stars according to Van Rhijn's figures. According to Dr. Chapman's table,* the equivalent for this range is $652 - 190 = 462$ stars. The difference does not seem great. The comparison is easily made by magnitudes, and it is seen that Chapman's figures are uniformly a little larger down to mag. 15. They show a maximum contribution for stars of mag. 10, whereas Table IV. places the maximum a little later, as though the Greenwich magnitudes were nominally rather smaller than the Groningen magnitudes. From the Greenwich numbers reduced to the visual scale Van Rhijn finds 0·024 for the total starlight per square degree at galactic latitude $\pm 10^\circ$ between mags. 5·5 and 15·5, as compared with 0·032 from the Groningen numbers. As the Greenwich figure for the whole sky seems to be actually greater than the Groningen figure, when both are expressed in the photographic scale, this is presumably another discrepancy resulting from the faulty system of weighting followed at Greenwich. The fact that this system led to serious consequences is the clearest indication of the inequalities of the star density in the Milky Way and of the need for ample material even when simple averages are required.

The (m, C_0) curve is shown in fig. 2. Its area, expressed in proper units, represents the total actinic light of all the stars according to magnitude. As far as mag. 16 it is well determined. Beyond this point its course is conjectural. The problem of determining the total starlight is equivalent to finding the area of this conjectural part extending to infinity. By other experience the C_0 series is known to be convergent, but that does not suffice to make its sum even approximately determinate. Of course one

* *M.N.*, **74**, 449.

would not be so pedantic as to deny that an observationally determined series $\frac{1}{2}, \frac{1}{4}, \frac{1}{8}, \ldots$ converges to the sum 1. How far

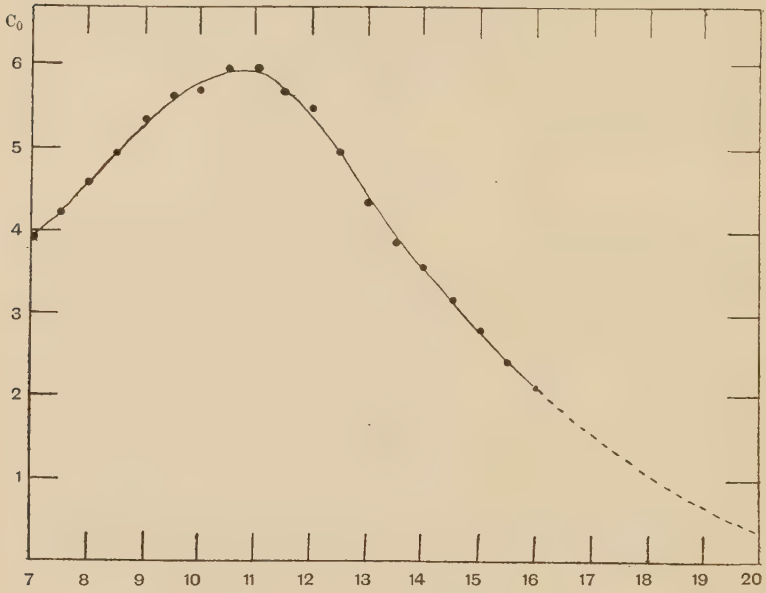


FIG. 2.

the above is an analogous case the graphical representation may help to judge.

SUMMARY.

17. (1) Counts of the stars on the Harvard Map of the Sky were made by H. Henie.* These counts have been further reduced and discussed by H. Nort, whose figures are used here. They refer to a limiting magnitude 11·0 (visual) or 11·5 (photographic), and indicate a total of rather more than a million stars for the whole sky.

(2) The number of stars per square degree in any part of the sky may be represented by the formula

$$\begin{aligned} &25{\cdot}5 + 5{\cdot}7 \sin\theta\cos\phi - 6{\cdot}8 \sin\theta\sin\phi - 4{\cdot}8\cos\theta \\ &\quad - 5{\cdot}0(1 + 3\cos 2\theta) + (-1{\cdot}3\cos\phi + 1{\cdot}3\sin\phi)\sin 2\theta \\ &\qquad + (-3{\cdot}2\cos 2\phi + 1{\cdot}7\sin 2\phi)(1 - \cos 2\theta) \\ &\quad + 1{\cdot}2\,P_3 + (-2{\cdot}7\cos\phi + 4{\cdot}3\sin\phi)(\tfrac{1}{6}\sin\theta + \tfrac{5}{6}\sin 3\theta) \\ &\qquad + (3{\cdot}5\cos 2\phi - 3{\cdot}5\sin 2\phi)(\tfrac{2}{3}\cos\theta - \tfrac{2}{3}\cos 3\theta) \\ &\qquad + (-6{\cdot}2\cos 3\phi + 8{\cdot}3\sin 3\phi)(\tfrac{3}{4}\sin\theta - \tfrac{1}{4}\sin 3\theta) \\ &\quad + 13{\cdot}2\,P_4 - 8{\cdot}7\,P_6 \end{aligned}$$

* *Meddelanden fr. Lunds Astr. Obs.*, ser. ii., No. 10.

where ϕ is the galactic longitude, θ the galactic N.P.D., and $P_3(\cos\theta)$, P_4 and P_6 are zonal harmonics.* This is simply a representation by functions for which the coefficients can be obtained independently and most simply by a natural system of weighting.

(3) The terms of the first order represent a gradient over the sky, with a minimum at $\alpha = 113^\circ$, $\delta = +55^\circ$ (Lynx) and a maximum, 20 stars per square degree higher, at the opposite point (Pavo).

(4) The terms of the second degree indicate a minimum axis within 5° of the galactic pole, a maximum axis within 2° of the galactic plane, and the intermediate axis in the direction of the vertex. This suggests that star-streaming will have a tendency to level the inequalities in the galactic density by diffusion.

(5) In the terms of the third order the sectorial harmonics are the most important. These may also be associated with the vertex, the line in galactic longitude 162° being a line of symmetry.

(6) The formula represents the zonal averages well, but some exceptional regions along the Milky Way naturally stand out.

(7) The curve traced by a radius vector representing by its length the star density in the corresponding direction in the galactic plane is a three-lobed figure which resembles in shape the figure representing the radial velocities of the giant stars, as given by Strömberg. But to be similarly placed the density figure requires rotation through 90° in the direction of decreasing galactic longitude.

(8) The zonal harmonics of even order have been deduced (Table IV.) from Mr. Van Rhijn's counts between the photographic magnitudes 7 and 16.

(9) By comparison with this independent material it is concluded that the limiting photographic magnitude of Nort's reduction is 11·49. The equivalent visual magnitude 11·00 is confirmed.

(10) Between magnitudes 7 and 16 it may sometimes be convenient to tabulate M, where

$$\log M = \log N - 0{\cdot}4(m - 10)$$

instead of log N. The factor 0·6, corresponding to a uniform distribution of equally bright stars, is excessive even for the brightest magnitudes, and the factor 0·4, corresponding to a star density inversely as the distance, would equally become excessive when applied to counts of still fainter stars.

(11) The coefficients of the zonal harmonics are tabulated on this reduced system. Remarks are added on the total light of the stars, in relation to which this system of tabulation is naturally appropriate.

* To be found in Dale's *Mathematical Tables* or Byerly's *Fourier's Series, etc.*

On the Nomenclature of U Boötis and χ Cygni.

By J. G. Hagen, S.J.

Astronomers specially interested in variable stars must be grateful to Professor Turner and Miss Blagg for publishing and discussing the observations of Baxendell, because they all shared in Argelander's apprehension that the "precious documents" of "this careful and reliable observer" might get lost, "like so many other observations made in this branch of astronomy" (see his *Beob. u. Rechn.* [1869] 46).

In the tenth and last instalment of Baxendell's observations, which has just appeared in *M.N.*, **78**, the nomenclature of two variables is mentioned as having been erroneously applied to different stars. It may not be without interest to have the early literature on the subject here put together.

1. The pseudo-variable *U Boötis*, to which reference is made on p. 491, is nearly ten degrees north of the real variable *U*, for it is *B.D.* + 28° 2355, mag. 9·5.

The star was announced as varying between mags. 9·5 and 13 by Chambers in his Catalogue (1864), No. 62, and attributed to Baxendell as discoverer (see *Ast. Nach.*, 1496). Schönfeld, after entering the "variable" in his first Catalogue (1866) as No. 62, observed it repeatedly, and in consequence omitted it from his second Catalogue (1875) as not confirmed.

2. The variable χ *Cygni* is referred to on pp. 507 and 541. The star was correctly identified with Bayer's χ by the discoverer Kirch in 1686. The subsequent error of Flamsteed, who took Bayer's χ to be his 17 *Cygni*, must have been due to the invisibility of χ at the time. Attention was called to the error by Olbers when he published his special chart for the variable in Lindenau's *Zeitschrift*, ii. (1816) 185. Again, in Argelander's *Uranometria* (1843) 39 the distinction between the variable χ and the double star 17 Flamsteed (Σ = 2580) is stated as clearly as could be desired.

Still, the error kept creeping into various lists, as *Piazzi* (xix. 295), Smyth's *Cycle* (1844), p. 457, Herschel's *Outlines* (*e.g.* 1851, pp. 558 and 567), Chambers' *Handbook* (1861), p. 492, and Burnham's *Gen. Catalogue* (1906), p. 192. Pogson had fallen into the error in his Catalogue of 1856, but recognised and corrected it afterwards.

Finally, E. J. Stone, in *M.N.*, **26**, 273 (1866), discussed the matter independently of Olbers and Argelander and came likewise to the conclusion "that the variable is really the χ *Cygni* of Bayer." The suggestion to distinguish the stars as χ_1 and χ_2 was first made by Stone, though the former distinction as χ and 17 *F* would seem to be less open to confusion and quite sufficient for all purposes. Clearness in the matter is the more important as 17 *F* has been used as comparison star by all observers of the variable without exception.

Vatican Observatory:
1918 *July* 31.

Double Stars measured at the Cape Observatory (Second Series).

By J. Voûte.

(*First Series, M.N.*, 75, 432.)

The measurements of position-angles and distances of all the double stars observed by me at the Cape will be published in detail later on in the *Cape Observatory Annals.*

I. *Visual Observations.*

The following series of observations were taken under the same conditions and by the same method as those given in the First Series, the position-angles being the mean of observations with and without a reversing prism, as proposed by Bosler and Salet.

	1900·0.			Epoch 1900+.	θ.	S.	Nts.
	h	m	° ′		°	″	
β 391 = κ_1 Sculptoris	0	4	−28 32	17·794	267·8	1·19	1
Innes 47		47	−44 15	16·895	2·0	1·13	1
Orm. Stone = Lal. 1458		47	−23 9	16·860	261·6	2·32	1
Innes 37 = Lac. 353	1	12	−69 21	17·808	285·3	0·86	1
h 3426		14	−66 36	17·808	336·0	2·52	1
h 2036		15	−16 20	16·898	7·6	1·66	2
h 3447 = τ Sculptoris		32	−30 25	16·904	95·8	1·77	1
h 3475		52	−60 48	16·898	54·1	2·66	2
Rümker 3 = θ Reticuli	4	17	−63 30	15·027	4·4	4·36	3
Rümker 4		22	−57 18	15·027	238·6	5·98	3
h 3752	5	18	−24 52	17·204	100·0	3·27	4
Cape 6	6	32	−38 44	17·230	60·7	1·12	2
Δ 51 = σ Argus	7	26	−43 6	17·273	72·9	22·70	3
Argelander 2		35	−20 3	17·244	330·0	2·91	4
Σ 1146		43	−11 57	17·176	9·3	2·87	2
Gilliss 91	8	14	−62 36	17·261	63·3	3·81	4
h 4073		15	−37 4	17·272	177·8	2·01	4
h 4104		26	−47 36	17·241	243·6	3·74	4
h 4128		37	−59 58	17·238	213·5	1·61	4
Innes 10 = δ Argus		42	−54 20	17·268	164·0	3·01	4
Copeland 1 = ψ Argus	9	27	−40 2	17·315	132·6	1·16	4
h 4252 = υ Argus		45	−64 36	17·352	126·7	5·02	4
h 4310	10	10	−83 36	17·362	169·2	3·89	4
Rümker 13		17	−55 32	17·352	100·8	6·95	4
h 4393		54	−68 30	17·374	131·8	8·44	2
Russell 165	11	8	−46 31	17·404	62·5	3·34	4
h 840 = γ Crateris		20	−17 8	17·374	94·4	5·00	4

	1900·0.		Epoch 1900 +.	θ.	S.	Nts.
	h m	° ′		°	″	
Brisbane 3574	11 20	−61 6	16·432	78·9	2·10	4
			17·355	81·2	2·00	5
Δ 109	24	−42 7	17·414	166·7	13·10	2
h 4475	44	−65 1	17·398	325·8	5·68	4
h 4498	12 1	−65 9	17·410	60·2	8·78	2
Σ 1604	4	−11 18	17·421	88·4	10·53	4
Jacob [8]	5	−34 9	16·522	19·7	3·49	4
Russell 193	13	−35 12	17·436	166·5	0·99	4
Russell 198	18	−51 38	16·438	51·6	3·36	2
α Crucis	21	−62 33	17·534	117·3	4·91	4
δ Corvi	25	−15 58	17·442	213·8	24·26	3
γ Centauri	36	−48 25	17·417	343·6	1·03	4
ι Crucis	40	−60 26	17·424	29·1	26·91	3
β Muscæ	40	−67 34	17·417	328·8	1·21	4
Hargrave 77	43	−65 3	17·427	9·9	8·64	2
β 341	58	−20 3	16·456	132·9	0·72	4
ξ_2 Centauri	13 1	−49 22	17·460	99·0	24·54	2
Δ 129 = θ Muscæ	2	−64 46	15·437	187·4	5·19	4
h 4586	21	−67 21	16·462	145·9	3·07	2
β 114	29	− 8 4	17·480	143·8	1·33	4
Δ 141 = φ Centauri	35	−54 3	15·437	163·7	5·23	4
Howe 23	38	−39 40	16·512	187·9	1·65	4
Σ 1788	50	− 7 34	16·494	81·2	3·04	4
Sellors 19	14 1	−49 24	17·480	263·2	1·06	4
Σ 1802	3	−12 27	16·476	281·8	5·48	4
Cordoba 33	8	−61 14	16·485	159·8	3·05	4
h 4671	17	−79 39	16·485	127·6	5·18	4
Σ 1837	19	−11 13	16·486	301·1	1·54	3
α Centauri (see Notes)	33	−60 25	14·973	218·2	17·14	5
			15·447	218·8	16·98	5
			16·502	219·5	16·52	6
			17·506	220·3	15·77	6
β 106 = μ Libræ	44	−13 44	16·469	345·3	2·06	3
h 4715	50	−47 28	15·438	278·2	2·60	3
β 239 = 59 Hydræ	53	−27 15	16·478	321·1	0·93	4
h 4722	53	−30 19	17·502	338·7	8·58	2
h 4753 = μ Lupi	15 12	−47 30	16·530	151·8	1·52	4
h 4757 = γ Circini	15	−58 58	15·538	69·4	1·16	2
Cape 16	22	−58 0	16·544	26·4	2·32	4
β 1114	23	−28 31	17·578	321·2	1·00	3

	1900·0.		Epoch 1900 +	θ.	S.	Nts.
	h m	° ′		°	″	
h 4776	15 24	−41 34	17·562	228·4	5·90	4
h 4777	25	−57 4	16·570	298·0	5·65	4
h 4773	25	−74 1	15·540	235·7	6·54	2
h 4788 = d Lupi	29	−44 37	17·502	359·5	2·49	4
β 122	34	−19 27	16·546	211·6	1·90	4
Rümker 20	39	−65 8	17·545	151·2	2·20	4
Δ 193	43	−54 45	16·606	17·2	19·76	4
Howe 41	57	−32 48	17·583	345·1	2·92	4
Σ 1998 = ξ Scorpii AB	59	−11 6	16·573	352·0	1·10	4
			17·582	353·5	1·08	4
AB-C			16·573	60·2	7·44	4
h 4845	16 17	−41 1	16·598	133·2	1·85	4
H 19 = ρ Ophiuchi	20	−23 13	16·578	352·4	3·50	3
α Scorpii = Antares	23	−26 13	16·569	274·9	3·18	6
h 4866	31	−56 48	16·547	124·5	3·64	4
Sellors 12	33	−47 35	16·567	173·4	1·30	4
β 1118 = η Ophiuchi	17 5	−15 36	15·554	243·1	0·75	2
Brisbane = Lac. 7194	11	−46 32	15·479	154·6	2·59	2
			16·572	156·9	2·78	4
			17·600	160·4	2·89	4
β 416 = Melb. 4 (see Notes)	12	−34 53	15·516	247·3	1·00	4
			16·554	242·3	1·82	5
			17·580	236·2	1·79	6
A-C = h 4935			16·576	133·8	30·80	4
β 126	14	−17 39	16·574	262·3	2·00	3
Russell 303	37	−54 5	16·577	109·4	3·35	3
β 245	18 4	−30 45	14·658	352·7	3·99	4
β 132	5	−19 52	17·648	214·8	1·10	4
β 760 = η Sagittarii	11	−36 48	17·132	101·2	3·58	4
Cape 35	14	−62 38	17·691	55·3	5·97	2
β 133	22	−26 42	17·648	258·3	1·68	4
Melbourne 5	24	−66 21	16·677	293·9	4·65	4
Orm. Stone = Lac. 7763	28	−34 54	15·619	136·2	1·89	2
h 5075	55	−63 56	16·686	111·7	1·80	4
β 142	19 23	−12 21	17·752	349·8	1·43	2
Σ 2545	33	−10 23	17·627	322·5	4·02	2
Cordoba [56]	34	−53 11	16·683	49·8	3·36	4
h 5140	40	−65 9	16·683	83·4	1·86	4
h 5163	56	−63 20	16·692	250·5	1·79	3
Orm. Stone	20 11	−32 55	16·684	302·4	2·26	2

	1900·0.			Epoch 1900 +.	θ.	S.	Nts.
	h	m	° ′		°	″	
β 763	20	17	−42 45	17·659	221·7	1·19	3
Russell 321		20	−37 44	16·693	70·8	1·02	2
π Capricorni		22	−18 32	17·196	144·2	3·36	2
H II 51 = ρ Capricorni		23	−18 9	16·736	169·4	2·42	4
Rümker 26		43	−62 48	15·750	92·0	2·80	2
h 5246	21	3	−54 59	16·300	126·3	3·47	4
h 5258 = θ Indi		13	−53 52	16·300	281·4	4·95	4
β 766		18	−41 26	17·179	288·2	0·80	2
Melb. 6 = β 767		21	−42 59	15·750	146·0	2·82	2
β 276 = η Pisc. Austr.		55	−28 56	16·755	115·1	2·03	3
h 5319	22	6	−38 48	16·523	121·5	2·19	3
h 5367		47	−33 24	17·717	268·2	4·49	1
Jacob 12 = θ Gruis	23	1	−44 4	16·898	38·2	2·04	2
Δ 251 = θ Phœnicis		34	−47 12	16·324	271·8	4·13	4
Sellors 14		45	−52 16	17·808	24·4	0·87	1

Notes.

α Centauri O–C (Doberck Eph., *A.N.*, 175, 209).			*β 416* O–C (Orbit, *M.N.*, 68, 153).		
	°	″		°	″
1914·50	−0·2	+0·36	1914·60	+1·3	−0·10
15·45	−0·3	+0·40	15·52	+2·9	−0·15
16·50	−0·4	+0·55	16·55	+2·6	−0·07
17·51	−0·6	+0·44	17·58	+1·4	−0·04

II. *Photographic Observations.*

The plates were taken with the astrophotographic refractor, the aperture of the object-glass being always reduced to 10 inches. The time of exposure was as short as possible, but sufficient to produce measurable images.

Every observation is the mean of measurements of 4–6 images in position-angle and distance. These measures were obtained with the Zeiss stereocomparator, in which one of the plate-holders is provided with a circle for measuring position-angles. The position-angles were measured by turning the plate-holder until the line joining the two stars was parallel to a vertical line in the microscope, the parallel being determined by making the vertical line pass through the measured images. These observations were made both with and without a reversing prism before the eye-piece of the microscope. The distances were measured by means of a micrometer screw moving the plate-holder in a vertical direction. The line joining the stars was put vertical, and the two stars were alternately brought under a mark in the microscope.

	1900·0.		Epoch 1900+.	θ.	S.	Pls.
	h m	° ′		°	″	
h 1957	0 17	−23 34	14·878	23·0	5·86	2
β 734	48	−24 33	16·925	343·8	11·24	1
Washburn 1	48	−25 19	16·925	12·3	6·04	1
h 3416	59	−60 38	16·925	127·9	5·68	1
θ Eridani	2 54	−40 42	16·923	87·2	8·52	1
Σ 436	3 36	−12 56	16·014	236·2	38·24	1
Δ 15	36	−40 41	17·007	237·0	8·00	2
Δ 16	45	−37 56	17·007	208·2	7·95	2
h 3611	53	−40 12	16·923	139·5	3·97	1
Σ 590	4 39	− 8 59	17·102	316·9	9·38	2
Δ 18 = ι Pictoris	49	−53 38	17·102	58·4	11·98	2
Σ 701	5 18	− 8 31	17·161	139·1	5·86	1
Δ 22	28	−42 22	16·128	170·4	7·58	2
h 3784	35	−46 9	15·190	65·4	5·50	1
h 3789	37	−50 11	15·208	0·4	9·03	2
h 3802	43	−55 46	15·190	303·8	7·60	1
So 504	54	−20 10	15·190	71·8	3·54	1
Arg. 12	6 1	−25 2	17·091	295·5	4·75	1
Δ 26	12	−65 30	17·102	117·0	21·08	2
Cordoba = C.G.A. 7790	20	−27 59	17·110	242·3	9·27	1
h 3858	22	−34 59	15·190	318·8	3·90	1
h 3871	30	−29 33	17·091	354·5	7·84	1
Δ 31	36	−48 8	15·165	318·8	13·28	1
Δ 32	39	−38 18	15·165	276·0	8·02	1
Σ 1011	56	−15 10	15·190	296·9	4·32	1
60 G. Puppis	7 1	−43 28	17·110	122·1	20·58	1
h 3928	2	−34 38	17·112	154·4	3·78	1
Σ 1031	4	−13 50	15·190	247·8	3·90	1
Δ 42 = γ Volantis	10	−70 20	16·138	299·8	13·79	2
Lalande 14,200	12	−23 8	17·137	59·4	27·16	2
Rümker 6	18	−52 8	16·172	20·9	9·74	2
h 3957	19	−35 44	17·262	194·6	7·86	2
h 3966	21	−37 6	16·172	141·4	7·40	2
So 552	30	−23 15	15·206	110·4	9·44	2
Σ 1121	32	−14 16	16·186	305·2	7·70	2
Δ 53	35	−26 34	16·186	316·8	9·95	2
Σ 1138	41	−14 27	17·162	338·8	17·05	1
h 4045	8 1	−50 10	15·206	227·7	4·89	2
h 4055	6	−69 34	17·112	8·0	6·24	1

	1900·0.			Epoch 1900 +	θ.	S.	Pls.
	h	m	° ′		°	″	
Δ 63	8	6	−42 21	15·202	81·8	5·83	3
Brisbane		16	−44 43	17·137	326·2	5·54	2
Δ 70		26	−44 23	15·210	349·6	5·13	2
Σ 1260		36	−11 49	15·228	301·0	5·03	2
Rümker 9		43	−58 22	15·210	290·0	4·56	2
Σ 1295		51	− 7 35	15·228	359·0	4·28	2
Rümker 10	9	16	−69 23	17·262	17·6	10·74	2
Cape 33		16	−69 58	15·230	336·9	4·56	1
Δ 78		26	−31 27	15·173	210·4	8·10	2
h 4224		32	−30 47	15·173	116·4	7·48	2
h 4249		44	−34 33	15·215	120·4	4·23	2
Rümker 12		53	−68 43	15·215	211·8	9·25	2
h 4283	10	1	−51 19	15·200	180·2	7·97	2
Σ 1416		7	−15 36	15·244	276·2	12·00	1
Δ 88 = *s* Velorum		28	−44 33	15·200	217·7	13·62	2
h 4393		54	−68 30	15·186	130·5	8·37	1
Jacob 7	11	25	−23 55	15·230	80·7	8·26	1
N Hydræ		27	−28 43	15·220	210·7	9·38	2
h 4460		34	−57 11	15·230	184·1	8·97	1
Howe 16		35	−36 53	15·228	102·8	3·28	2
h 4475		44	−61 1	15·204	325·8	6·00	2
h 4481		52	−21 59	15·228	194·8	3·48	2
h 4498	12	1	−65 9	16·504	59·6	8·62	1
Lal. 96		10	− 6 42	15·230	277·9	7·51	1
α Crucis		21	−62 33	15·229	115·9	5·04	2
Σ 1669		36	−12 28	15·867	304·5	6·25	2
γ Virginis		37	− 0 54	15·227	324·6	6·38	2
h 4545		39	−74 38	17·446	191·6	9·48	1
ι Crucis		40	−60 26	14·293	29·7	27·24	1
μ Crucis		49	−56 38	15·230	17·4	35·34	1
Δ 127		54	−55 22	17·446	126·2	17·22	1
h 4563		56	−33 5	16·488	236·2	7·05	2
Cordoba [29]		59	−46 2	16·457	96·9	4·89	1
ξ_2 Centauri	13	1	−49 22	14·298	100·6	25·38	1
θ Muscæ		2	−64 46	15·897	186·2	5·31	2
54 Virginis		8	−18 18	16·462	34·2	5·80	2
Σ 1738		18	−14 24	16·520	283·4	4·02	1
h 4587		21	−42 32	15·271	87·8	5·46	1
So 651		31	−25 59	16·462	190·2	10·36	2

	1900·0.			Epoch 1900+.	θ	S.	Pls.
	h	m	° ′		°	″	
Δ 141	13	35	−54 3	15·908	162·8	5·41	2
h 4608		37	−33 28	15·910	790·0	4·34	2
Δ 143		42	−61 36	15·910	36·1	12·84	2
κ Centauri		46	−32 30	15·268	107·8	8·26	2
Δ 151		51	−55 33	15·896	54·2	17·55	2
Δ 159	14	15	−58 0	15·266	158·7	9·60	1
h 4671		17	−79 39	16·550	125·5	4·66	1
Σ 1833		17	− 7 19	15·271	168·8	5·52	1
α Centauri		33	−60 25	15·510	218·8	17·07	2
				17·449	221·1	16·24	1
Δ 168		36	−54 45	15·268	201·8	6·09	2
m Hydræ		40	−25 1	15·268	127·4	8·90	2
κ Lupi	15	5	−48 22	15·474	144·0	27·48	1
Δ 195		48	−50 2	16·519	8·6	12·16	2
η Lupi		54	−38 7	16·501	20·0	14·98	1
Cordoba [43]		56	−37 46	16·501	140·0	4·62	1
Brisbane = Lac. 6706	16	3	−32 23	16·519	84·9	8·13	2
h 4836		11	−34 34	16·519	297·6	4·74	2
h 4848		18	−32 58	16·519	152·5	6·72	2
h 4850		18	−29 28	16·519	352·0	6·57	2
ε Normæ		20	−47 20	16·537	334·2	23·04	1
Δ 213	17	3	−46 37	16·537	166·2	8·59	1
h 4970		35	−48 35	16·537	68·7	8·16	1
h 5003		53	−30 15	16·537	104·6	5·89	1
h 5066	18	44	−41 11	14·728	88·5	11·37	1
Brisbane = Lac. 7947		54	−37 12	14·728	180·8	13·35	1
Howe 46	19	9	−16 9	14·728	162·1	5·46	1
h 596		12	−16 9	14·728	17·8	9·33	1
So 716		12	−16 8	14·728	197·6	5·33	1
h 5167	20	3	−63 55	14·734	34·4	7·76	2
Harv. = Lac. 8343 AB		5	−64 44	14·728	303·6	17·28	1
AC				14·728	335·2	29·88	1
h 5177		7	−57 16	14·753	28·4	8·13	1
β 166	21	48	−20 29	14·739	74·6	4·80	1
So 802		57	−17 27	14·800	243·4	3·88	2
41 Aquarii	22	9	−21 34	14·788	115·0	4·78	2
f Aquarii		21	−17 15	14·788	311·4	6·72	2
h 3114		22	−17 48	14·720	93·9	7·80	1
Lalande 180		34	−13 8	14·761	307·8	3·33	1

	1900·0.		Epoch 1900 +.	θ.	S.	Pls.
	h m	° ′		°	″	
h 5382	22 59	−51 54	14·761	49·8	7·86	1
Δ 246	23 2	−51 14	14·761	258·7	8·70	1
h 5392	13	−58 51	14·723	328·6	24·00	1
Σ 2998=94 Aquarii	14	−14 0	16·925	346·8	13·51	1
Δ 251	34	−47 12	14·761	271·4	3·75	1
So and *h* 356	41	−19 14	14·878	136·0	6·52	2
Lalande 192=Δ 253	49	−27 36	14·878	269·4	6·92	2

Note on Espin's Latest List of New Double Stars.

By Eric Doolittle.

This list comprises Nos. 1601 to 1705, and it is followed in the *Monthly Notices*, 78, 195, by a list of 41 pairs discovered by Mr. W. Milburn. In re-reducing and copying these 41 pairs no errors and no misprints were found, and there were but few identities with previously known pairs. This last was doubtless because the discoveries were compared with the valuable Catalogue of Jonckheere, recently published as vol. lxi. of the *Memoirs of the Royal Astronomical Society*. The following five pairs are, however, not new:

Espin 1645. This is A.G. 200 (Burnham's General Catalogue, 7483).

1650. This was first measured by Leonard, though the measures do not agree well. Leonard obtains:

1916.72 153°·4 1″·38 9·9 10·6 2*n* (Y.O. 12-inch).

1687. This is Roe 44. Discovered by Roe in 1910 (*A.N.*, 4467).

Milburn 20. Entered in the previous list as Espin 1677, and the measures there credited to Espin.

32. This is Roe 47. Measured by Roe in 1910, who reverses the quadrant (*A.N.*, 4467).

The Flower Observatory:
1918 *June* 10.

Jupiter's 4th Satellite. By F. Sargent.

On September 2 the writer commenced observations of Jupiter shortly after 14 hrs.

At the limb of the planet in high northern latitude a satellite was seen passing to occultation, and already partly obscured. The time was noted as 14 hrs. 10 mins. Five minutes later the satellite had completely disappeared, and notwithstanding careful and repeated scrutiny it was not again seen until 14 hrs. 52 mins., when it was suspected, but was not seen with certainty until five minutes later. At 15 hrs. 20 mins. it was still a matter of uncertainty as to whether the satellite was "clear," but at 15 hrs. 25 mins. it was definitely so.

The observations were made with a 5-inch Cooke refractor and a 10½-inch Newtonian reflector, using powers of from 120 to 312 diameters.

Reference to the *Nautical Almanac* identifies the satellite as Sat. IV., which it was predicted would be in geocentric conjunction on Sept. 2 at 14 hrs. 30·7 mins., but no reference is made to "occultation" as being an attendant phenomenon. For this reason it seems desirable to place the foregoing observations on record.

Further phenomena of a similar character are predicted as occurring at intervals of approximately seventeen days, but in each instance occultation is forecasted, the earliest to occur during the usual observing hours being on November 8, when geocentric conjunction is computed as occurring at 14 hrs. 42·8 mins.

114 *Bishop Road, Horfield, Bristol:*
1918 *September* 27.

The following Report was received too late for insertion in the Annual Report of the Council.

Hill Observatory, Salcombe Regis, Sidmouth, Devon.
Report for the Year 1917.

In consequence of the continuation of the war and the absence of all observers, the Observatory has remained closed and no observations have been made.

The instruments and buildings are in good condition, with the exception of the Kensington dome. Owing to shortage of labour, consequent upon the war, the slight settlement at one point under the rail of this dome cannot be taken in hand at present.

A further contribution to the library has been made by the

Director, and many transactions and pamphlets have been received from various observatories.

A new Bulletin, the sixth, is in preparation by the Director. It continues the discussion on the classification of stars, and points out the similarity of the three curves plotting the spectra of stars in the three catalogues already issued. It is pointed out that these curves may suggest that the stars of our system were formed at two different epochs, and that a test of this view may be found by studying the characteristics of the stars belonging to each of the two systems.

LIST OF ADDITIONS

TO THE LIBRARY

OF THE SOCIETY

JUNE 1917 TO JUNE 1918.

An asterisk (*) indicates that the work is an excerpt.

Acta Mathematica. Zeitschrift, herausgegeben von G. Mittag-Leffler. Band 41, pt. 1.
(*Purchased.*) 4to. Stockholm, 1916

Allegheny Observatory:
Publications. Vol. 4, No. 1.
(*Observatory.*) 4to. Lancaster, Pa., 1917

American Journal of Mathematics. Edited by Frank Morley. Published under the auspices of the Johns Hopkins University. Vol. 39, No. 3, 4; Vol. 40, No. 1, 2.
(*Editor.*) 4to. Baltimore, 1917–1918

American Journal of Science. Editor E. S. Dana [and others]. Fourth series, Vol. 43, 44, 45 (No. 258–269).
(*Editors.*) 8vo. New Haven, 1917–1918

Arcetri, Reale Osservatorio:
Pubblicazioni del R. Istituto di studi superiori pratici e di perfezionamento, fasc. 35.
(*Observatory.*) 4to. Firenze, 1917
A. Abetti, Osservazioni astronomiche fatte . . . 1916.

Astronomical Herald (the). Published by the Astronomical Society of Japan [in Japanese]. Vol. 10, No. 1–12.
(*Society.*) 4to. 1917–1918

Astronomical Journal. Founded by B. A. Gould. Vol. 30, 31 (No. 712–733).
(*Editor.*) 4to. Boston, 1917–1918

Astronomische Nachrichten:
——: Begründet von H. C. Schumacher: herausgegeben von H. Kobold. Band 204–206 (No. 4884–4904; 4906–7; 4909–11; 4929, 4931, 4933).
(*Editor.*) 4to. Kiel, 1917–1918

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(*Editors.*) 8vo. Chicago, 1917–1918
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Barcelona, Sociedad Astronomica:
Boletin, Año 8, 9. (No. 71–80.)
(*Society.*) 8vo. Barcelona, 1917–1918

Basel, Naturforschende Gesellschaft:
Verhandlungen; Band 28.
(*Society.*) 8vo. Basel, 1917

Belfast Natural History and Philosophical Society:
Report and Proceedings, 1916, 1917.
(*Society.*) 8vo. Belfast, 1918

Boccardi (Giovanni):
*Perchè e come si arrotonda l' ultima cifra.
(*Author.*) 8vo. Torino, 1917
——: *Sur la Polhodie du sphéroïde terrestre.
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Breson (Elias):
Communications about Observations of the Planet Jupiter during opposition, 1915–1916.
8vo. Helsingör, 1918

British Association for the Advancement of Science:
Report of the 86th meeting, held in Newcastle, 1916.
(*Association.*) 8vo. London, 1917

Bulletin Astronomique. Fondé en 1884 par E. Mouchez et F. Tisserand. Publié par l'Observatoire de Paris. Tome 34, No. 3–12.
(*Purchased.*) 8vo. Paris, 1917

Bulletin des Sciences Mathématiques. Rédigé par G. Darboux et E. Picard. Série 2. Tome 41, No. 5–12; Tome 42, No. 1–4.
(*Editors.*) 8vo. Paris, 1917–1918

Calcutta, Astronomical Society of India:
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(*Society.*) 8vo. Calcutta, 1917
——: Monthly Notices, 1917 May, June, Sept.–Dec.; 1918 Feb.–April.
(*Society.*) 8vo. Calcutta, 1918
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(*Society.*) 8vo. Calcutta 1918

Cambridge Philosophical Society:
——: Proceedings, Vol. 19, pt. 2, 3.
(*Society.*) 8vo. Cambridge, 1917
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Fourth and Fifth Annual Reports of the Director . . . to the Solar Physics Committee, 1916–1917.
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Cape of Good Hope, Royal Observatory:
——: Independent Day-Numbers for the year 1918–1919.
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Transactions, Vol. 5, pt. 6; Vol. 6, pt. 1–4.
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Memorie . . . Fondata da P. Tacchini: pubblicazione mensile continuata per cura di A. Riccò. Serie 2. Vol. 6, Disp. 5–12; Vol. 7, Disp. 1–3.
(*Society.*) 4to. Catania, 1917–1918

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(*Editor.*) 8vo. Stevenage, 1918

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The Monthly Register, Vol. 9, No. 1, 2.
(*The Editor.*) 8vo. Chicago, 1916–1917

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(*Society.*) 4to. Kjöbenhavn, 1916–1917
—: Mathematisk-fysiske Meddelelser, Vol. 1, No. 1, 2.
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The Principle of Relativity.
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Alæ sev Scalæ Mathematicæ, quibus visibilium remotissima Cœlorum Theatra conscendi, & Planetarum omnium itinera nouis & inauditis Methodis explorari: tum huius portentosi Syderis in Mundi Boreali plaga insolito fulgore coruscantis, Distantia, & Magnitudo immensa, Situsq: protinùs tremendus indagari, Dei'g; stupendum ostentum Terricolis expositum, cognosci liquidissimè possit.
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The Theory of Optics. Translated from the German by C. Riborg Mann and Robert A. Millikan.
(*Purchased.*) 8vo. London, 1902

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Report of Committee to consider Daylight Saving in Egypt.
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Fiji, Trigonometrical Survey:
Report of the Trigonometrical Survey of Vanua Levu and Taveuni. By G. T. McCaw.
(*Crown Agents for the Colonies.*) 4to. London, 1917

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(*Author.*) 12mo. Paris

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* The total solar eclipse of 1918, June 8: a reconnaissance.
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Gautier (Raoul):
Rapport sur le Concours de réglage de chronomètres, 1916.
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(*Observatory.*) 4to. London, 1918

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(*Observatory.*) 4to. Cambridge, Mass., 1917
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(*Observatory.*) 4to. Cambridge, Mass., 1917–1918

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The distances, absolute magnitudes, and spectra of 734 stars, arranged for use with ordinary Star Maps (also a facsimile of the MS.)
(*Author.*) 8vo. London [1917]

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*Erforschung der Schwere durch Galilei, Huygens, Newton, als Grundlage der rationellen Kinematik und Dynamik.
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Jena Glass and its scientific and industrial applications . . . Translated and edited by J. D. and Alice Everett.
(*Purchased.*) 8vo. London, 1902

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Œuvres complètes . . . publiées par la Société Hollandaise des Sciences, Tome 13, fasc. 1, 2.
(*Purchased.*) 4to. La Haye, 1917

Hyderabad, Nizamiah Observatory:
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